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REPORT #15

FOREST AND RANGE EVALUATION PROGRAM

April 2008

Sampling Intensity for Stand-Level Biodiversity Surveys

Nancy Densmore
Amanda F. Linnell Nemec

BRITISH COLUMBIA
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Sustainability of Forest and Range Resources Through Science and Stewardship

MINISTRY OF FORESTS AND RANGE
FOREST AND RANGE EVALUATION PROGRAM

SAMPLING INTENSITY FOR STAND-LEVEL BIODIVERSITY SURVEYS

Nancy Densmore
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FREP'S MISSION IS TO BE A WORLD LEADER IN RESOURCE STEWARDSHIP MONITORING AND EFFECTIVENESS EVALUATIONS; PROVIDING THE SCIENCE-BASED INFORMATION NEEDED FOR DECISION-MAKING AND CONTINUOUS IMPROVEMENT OF BRITISH COLUMBIA'S FOREST AND RANGE PRACTICES, POLICIES AND LEGISLATION

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Management of forest and range resources is a complex process that often involves the balancing of ecological, social, and economic considerations. This evaluation report represents one facet of this process. Based on monitoring data and analysis, the author offers the following recommendations to those who develop and implement forest and range management policy, plans, and practices.

Library and Archives Canada Cataloguing in Publication Data

Densmore, Nancy.
Linnell Nemec, Amanda F.
Sampling intensity for stand-level biodiversity surveys
(FREP report ; #15)

At head of title: Ministry of Forests and Range, Forest and Range Evaluation Program.
Issued also on the internet
Includes biographical references: p.
ISBN 978-0-7726-6027-5

1. Forests and forestry - British Columbia. 2. Forest surveys - British Columbia. 3. Biodiversity - Monitoring - British Columbia. 4. Forest management - Environmental aspects - British Columbia. 5. Forest ecology - British Columbia. I. Nemec, Amanda F. Linnell (Amanda Frances Linnell). II. British Columbia. Ministry of Forests and Range. III. British Columbia. Forest and Range Evaluation Program. IV. Title. V. Series.

SD438.B7D46 2008 333.7509711 C2008-960133-5

Citation:
B.C. Ministry of Forests & Range. 2008. Sampling Intensity for Stand-level Biodiversity Surveys. B.C. Min. For. Ran., For. Prac. Br., Victoria, B.C. FREP Ser. 15. <http://www.for.gov.bc.ca/hfp/frep/publications/index.htm>

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ABSTRACT

Two harvested cutblocks were thoroughly sampled using the Forest and Range Evaluation Program sampling methodology for stand-level biodiversity monitoring. This was done to assess the validity of the recommended plot sample intensity. The number of plots established was double or more the recommended plot sample intensity as described in the Protocol for Stand-level Biodiversity Monitoring (Province of British Columbia, 2007). Tree and coarse woody debris indicators were estimated based on varying numbers of the established plots. No bias was found in the estimation of the indicators for large trees, large snags, CWD volume or density of long pieces of CWD. The means of these indicators were relatively stable at all sampling intensity. However the precision of the mean (standard error) for the large snags density indicator is low at the recommended sampling density. The mean of number of species sampled does have an inherent bias influenced by sampling intensity. The number of species found tends to increase with increased number of sample plots.

ACKNOWLEDGEMENTS

Acknowledgements: Field work was done by Nancy Densmore and Kevin Kilpatrick, working the first day of two days on the Kalum Forest District cutblock with Steve Biagioni and the first of two days on the 100 Mile House Forest District cutblock with Darius Low and Dustin Price. Amanda Nemec performed the data analysis.

Thanks to Kevin Kilpatrick, Peter Bradford, Wendy Bergerud, Darius Low, and Hubert Burger for reviewing the draft document.

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1.0 INTRODUCTION

Resource stewardship monitoring (RSM) conducted through the Forest and Range Evaluation Program (FREP) provides a mechanism for continuous improvement of forest stewardship. During RSM, on-the-ground forest practices are assessed to determine whether they correlate with approved Forest Stewardship Plan results and strategies. Monitoring activities also help to determine whether *Forest and Range Practices Act* (*FRPA*) resource value objectives are being met.

Resource stewardship monitoring for stand-level biodiversity uses a sampling methodology that incorporates timber cruising techniques for standing trees and a line-transect survey for coarse woody debris (CWD). Overall biodiversity attributes (e.g., evidence of wildlife use, presence of ecological anchors) are also assessed through an overview of the cutblock or a stratum within the cutblock. Tree and CWD data are collected from plots or transects randomly located on the cutblock. Indicators, such as density of large trees and volume of CWD, are estimated from this plot data and compared against baseline values to assess the state of biodiversity in a group of cutblocks. For tree indicators, baseline values are obtained from timber cruise data for comparative cutblocks in the same ecosystem. Indicators for CWD from harvest areas are compared against indicators found in patch areas of the same ecosystem.

In a cutblock's Net Area to be Reforested (NAR),[1] the recommended plot sampling intensity is three plots. The recommended plot sampling intensity for patch retention is one plot per hectare of each patch, to a maximum of five plots per patch. The sampling intensity exercise documented in this report had two objectives:

1. to assess the change in mean (bias) and precision (standard error around the mean) of tree and CWD indicators as sample intensity increases, and
2. to determine the impact on assessment of biodiversity values for a cutblock.

During the 2007 field season, two cutblocks were intensively sampled for stand-level biodiversity to allow an assessment of suggested sample size. The sampling methodology used is outlined in the FREP Protocol for Stand-level Biodiversity Monitoring (Province of British Columbia 2007). Sampling intensity was increased to at least double that recommended in the Protocol. For each cutblock, select indicators were estimated from the plot data for a variety of combinations of plot sampling intensities and the results were summarized.

2.0 METHODOLOGY

2.1 *Block Description*

Two blocks were non-randomly selected from the random list of cutblocks available for stand-level biodiversity sampling in the 2007 field season. A coastal block (Coastal Western Hemlock [CWH] biogeoclimatic zone; Figure 1) was chosen from the Kalum Forest District (DKM) list and an interior block (Sub-Boreal Pine–Spruce [SBPS] biogeoclimatic zone; Figure 2) was chosen from the 100 Mile House Forest District (DMH) list. Both blocks were smaller than 60 ha, contained a variety of retention, and were within a 1-hour drive of a town (see Table 1).

Table 1. *Details of two cutblocks chosen for intensive sampling exercise*

	Kalum Forest District cutblock	100 Mile House Forest District cutblock
Opening ID	96275	2964
Gross area (ha)	38.2	49.4
NAR (ha)	28	41.8
Wildlife tree patches (ha)	11	3.3
Dispersed retention in NAR	None	3 distinct strata of differing density
Biogeoclimatic Ecosystem Classification	CWHws 01/04	SBPSmk 01

1 NAR is the area of a cutblock where harvesting took place and is inclusive of areas of dispersed single tree retention, and clear-cut areas.

Figure 1. *North end of block Kalum Forest District Block Opening ID 96275*

Figure 2. *Kevin and dispersed retention in 100 Mile House Forest District Opening ID 2964*

Thirty-six plots were established on the Kalum cutblock (eight plots in the NAR and the remainder in the patches), which is more than double the suggested number of plots (12). Twenty-two plots were established on the 100 Mile House cutblock (12 plots in the patch and the remainder in the dispersed areas), which is more than triple the suggested number of plots (6).

2.2 *Data Analysis*

Plot data was entered into the FREP Information Management System (IMS). Biodiversity indicators were estimated for each cutblock using a SAS program developed by Amanda Nemec. These indicators included:

- Number of tree species found on the cutblock
- Stems per hectare of large trees (diameter ≥ 50 cm for DMH and ≥ 70 cm for DKM)
- Stems per hectare of functional snags (dead trees ≥ 30 cm diameter and ≥ 10 m height)
- Volume (cubic metres per hectare) of coarse woody debris (CWD) in the harvest area
- Volume (cubic metres per hectare) of CWD in the patch area
- Density of long pieces (≥ 10 m) of CWD in the harvest area (pieces per hectare)
- Density of long pieces of CWD in the patch area

Plots from the DKM and DMH cutblocks were subsampled according to five or six sampling designs, respectively (see Tables 3 and 5). These sampling designs correspond roughly to:

- the current protocol (i.e., three plots in the harvested area [DKM] and 1 plot per hectare for patch strata [DMH]),
- reduced sampling rates of about one third (DKM) and one half (DMH) the current recommendation, and
- increased rates of double (DKM) and triple (DMH) the recommended rate.

For each sampling design, the specified number of plots was selected at random without replacement from the plots in the applicable strata and the corresponding cutblock indicators were calculated as a weighted (by area) average of the stratum means. This process was replicated 50 times for each sampling design and once for the full sample (all plots collected for each cutblock). A result summary was generated by calculating the mean, standard deviation (equivalent to standard error of the block mean), and minimum and maximum of the 50 block averages. This data is presented for each indicator as box plots, which show the distribution of the (50) individual values for each design (Figures 3–18).

2.3 *Baseline Tree Indicators*

FREP analysis of stand-level biodiversity currently utilizes baseline data from British Columbia Timber Sales (BCTS) cruise plots for the same ecosystem. Baseline indicators for the CWHws and SBPSmk subzones corresponding to the DKM and DMH cutblocks are summarized in Table 2. Risk rankings for FREP-sampled cutblocks can be approximated by assessing where the indicators for the blocks fall in relation to the full range of indicators for all the baseline cruise sample cutblocks. A moderate precision (standard error) of 35% of the indicator estimate is targeted from the stand-level biodiversity sampling for each cutblock. Therefore, because FREP RSM uses relatively light sampling intensity, interpretation is best done with merged cutblock data. With the indicator precision levels targeted, an evaluation of a single cutblock may not place it appropriately in the quartile from the baseline data. An assessment of many cutblocks gives a better assessment.

Table 2. *Baseline quartiles for tree indicators*

		No. species			Functional snags			50-cm trees			70-cm trees		
BEC subzone	**No. blocks**	25%	50%	75%	25%	50%	75%	25%	50%	75%	25%	50%	75%
CWHws	10	3	3.5	4	15	16	23	84	103	139	20	30	45
SBPSmk	43	3	3	4	0	5	23	0	1	5	0	0	0

3.0 100 MILE HOUSE FOREST DISTRICT CUTBLOCK

The sampling designs and results for the 100 Mile House Forest District cutblock (Opening ID 2964) are summarized in Tables 3 and 4, respectively.

Table 3. *Sampling designs for dispersed (D) and patch (P) strata (NAR and wildlife tree patch [WTP]) in the 100 Mile House Forest District cutblock (Opening ID 2964)*

	No. plots sampled per stratum					
	NAR1	NAR2	NAR3	WTP1		
	DW[b]	DW	DW	PW		
Design	**9 ha**	**25.6 ha**	**10.2 ha**	**3.3 ha**	**Total no. plots**	**No. replicates**
D = 1; P = 1/3 ha	1	1	1	1	4	50
D = 1; P = 1/ha[a]	1	1	1	3	6	50
D = 2; P = 1/2 ha	2	2	2	2	8	50
D = 3; P = 1/ha	3	3	3	3	12	50
D = all; P = 2/ha	3	4	3	7	17	50
D = all; P = 3/ha	3	4	3	10	20	50
D = all; P = all	3	4	3	12	22	1

a Currently recommended sampling intensity.

b Stratum type codes used: dispersed wildlife (DW) – dispersed trees left outside of RMA and designated as wildlife trees, patch wildlife (PW) – tree patch left outside of riparian management area and designated as a wildlife tree patch.

Table 4. *Summary statistics for six sampling designs plus all plots in the 100 Mile House Forest District cutblock (Opening ID 2964)*

Indicator	Statistic	D = 1 P = 1/3 ha (4 plots)	D = 1 P = 1/ha (6 plots)[a]	D = 2 P = 1/2 ha (8 plots)	D = 3 P = 1/ha (12 plots)	D = all P = 2/ha (17 plots)	D = all P = 3/ha (20 plots)	D = all P = all (22 plots)
Class 3+ wildlife trees height ≥ 10 m and dbh ≥ 30 cm (no. per hectare)	Mean	5.4	2.9	2.9	3.3	3.2	3.2	3.1
	S.D.	6.7	2.6	3.2	2.6	1.1	0.6	
	Min.	0.0	0.0	0.0	0.0	1.0	2.2	
	Max.	21.5	9.8	10.0	10.7	4.9	3.7	
Trees with dbh ≥ 50 cm (no. per hectare)	Mean	8.4	8.4	8.4	8.2	8.0	7.9	7.9
	S.D.	5.3	4.2	3.3	1.0	0.4	0.2	
	Min.	1.1	1.2	3.3	6.4	7.3	7.3	
	Max.	21.4	15.9	14.2	10.0	8.4	8.1	
Number of tree species	Mean	4.4	4.7	4.9	5.1	5.9	6.0	6.0
	S.D.	0.70	0.71	0.67	0.68	0.35	0.20	
	Min.	3	4	4	4	5	5	
	Max.	6	6	6	6	6	6	
Estimated number of tree species	Mean	5.3	5.5	5.0	5.4	6.5	6.4	6.0
	S.D.	1.8	1.6	0.9	1.1	0.7	0.6	
	Min.	3.0	4.0	4.0	4.0	5.0	5.0	
	Max.	11.0	9.0	7.0	7.0	7.0	7.0	
CWD volume (m^3/ha) – patch	Mean	31.8	32.5	28.4	30.4	30.7	31.4	31.0
	S.D.	16.2	8.5	10.6	8.9	4.7	1.9	
	Min.	9.3	14.4	9.7	11.2	20.6	26.7	
	Max.	61.6	51.7	55.9	49.6	37.5	34.8	
CWD volume (m^3/ha) – harvest	Mean	48.6	42.0	46.8	45.6	47.0	47.0	47.0
	S.D.	30.4	27.2	17.8	9.2	0.0	0.0	
	Min.	16.9	14.7	20.0	31.6	47.0	47.0	
	Max.	103.9	101.7	71.8	54.9	47.0	47.0	
CWD length ≥ 10 m (no. per hectare) – patch	Mean	76.2	87.7	76.9	71.9	75.4	80.6	79.0
	S.D.	80.0	48.4	61.9	40.8	26.0	10.4	
	Min.	0.0	13.3	0.0	11.8	27.7	55.2	
	Max.	267.8	203.3	240.6	160.4	119.0	94.8	
CWD length ≥ 10 m (no. per hectare) – harvest	Mean	27.8	23.1	24.1	23.7	23.1	23.1	23.1
	S.D.	24.5	22.8	13.2	8.2	0.0	0.0	
	Min.	0.0	0.0	0.0	11.8	23.1	23.1	
	Max.	61.0	61.0	45.3	30.2	23.1	23.1	

a Currently recommended sampling intensity.

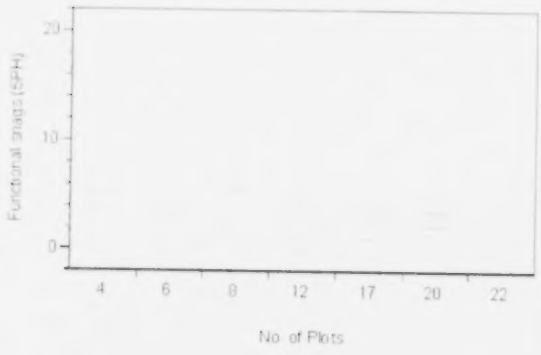

Figure 3. *Functional snags (stems per hectare) by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers (red lines extending from the box) extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The mean density of functional snags (50 replicates) for the sampling designs with more than four plots is very close to the mean of 3.1 obtained from the full sample of 22 plots. This suggests an absence of bias for these designs. There is, however, low precision around the mean (> 34% of the estimate) for functional snag density for all sample designs less than the 17-plot design.

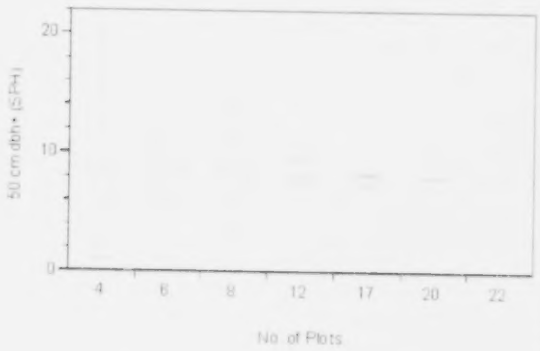

Figure 4. *Large trees 50 cm dbh+ (stems per hectare) by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The mean density of large trees (> 50 cm) obtained from all sampling designs is very consistent, ranging from 8.4 to 7.9 stems per hectare. For the 12-plot design, which has three plots in each of the three dispersed strata (total of nine plots in the harvest area) and three plots in the wildlife tree patches, the precision increases noticeably (to about 12.2% of the estimate). In areas with fairly high-dispersed retention such as this 100 Mile House block, it is advisable to increase the density of plots in the dispersed retention areas to account for variability in density of large trees. The 8-plot design had six plots in the harvest area and two plots in the wildlife tree patch—this gave a precision of about 40% of the estimate. A fair precision for the large tree indicator would likely be obtained with nine or more plots.

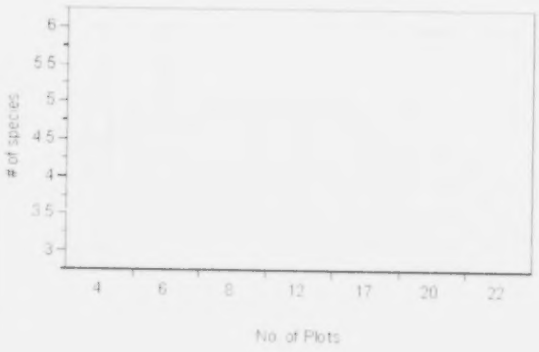

Figure 5. *Number of tree species by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The mean number of tree species found on the cutblock (i.e., number of species in the sample) increases steadily with increasing number of plots in the sampling design, up to the 17-plot design. As sampling intensity increases (i.e., as plot density increases), more tree species are expected to be found. The study results show that to make a fair assessment of biodiversity based on this indicator it is important to ensure similar plot density in the baseline cruise and FREP monitoring.

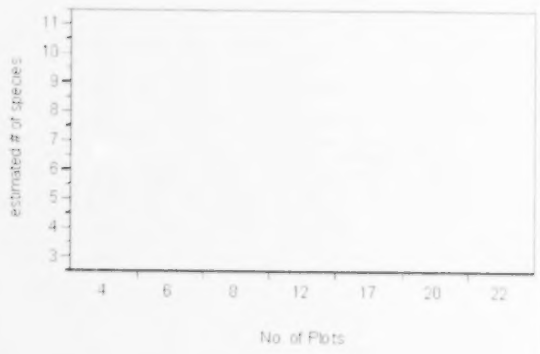

Figure 6. *Estimated number of tree species by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

To reduce the bias associated with variable sampling intensity, total number of species (i.e., species found on cutblock plus missed species) was estimated by the (bias-corrected) method proposed by Chao (1984) (Figure 6). Replacing the number of species found by an estimate of the total number of species decreased the range of the means between the different sampling designs. Such a method is recommended for future analysis of tree species and can be applied to both the cruise baseline data and the FREP monitoring data.

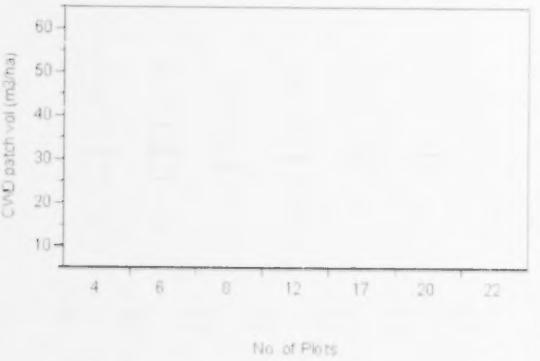

Figure 7. *Coarse woody debris volume (m^3/ha) by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The CWD volume shown in figure 7comes only from the plots established in retention patches. The 4-plot sampling design contained only one plot in the wildlife tree patch. The 6- and 12-plot sampling designs both contained three plots in the wildlife tree patch. The 8-plot sampling design contained only two wildlife tree patch plots. The 17-, 20- and 22-plot sampling designs contained 7, 10, and 12 wildlife tree patch plots, respectively. The mean volume was consistent amongst all sample designs, though the precision surrounding the 4-plot design (only one wildlife tree patch plot) was low at about 51% of the estimate. The recommended plot density of one plot per hectare of patch retention found in the 6-plot design (variability of 26% of the estimate) and 12-plot design (29% of the estimate) provides sufficient precision.

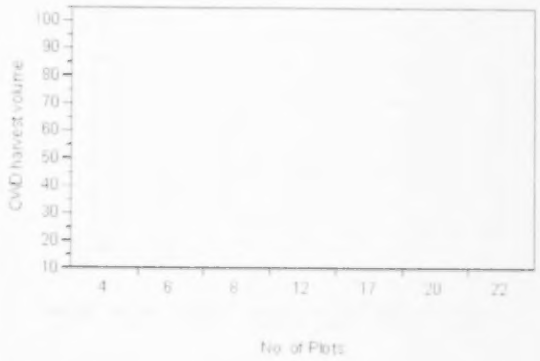

Figure 8. *Coarse woody debris harvest volume by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

Coarse woody debris harvest volume is calculated only from the harvest area (or dispersed) plots. The 4-, 6-, 8-, and 12-plot sampling designs contained three, three, six, and nine harvest area plots, respectively. The 17-, 20-, and 22-plot sampling designs all contained 10 dispersed plots. Precision increases with increasing number of harvest plots, from about 62% of the estimate for the 4-plot design (three harvest plots) to about 20% of the estimate for the 12-plot design (nine harvest area plots). The 8-plot design (six harvest plots) has a precision of about 38% of the estimate. The mean CWD harvest volume is consistent indicating no bias in the sampling.

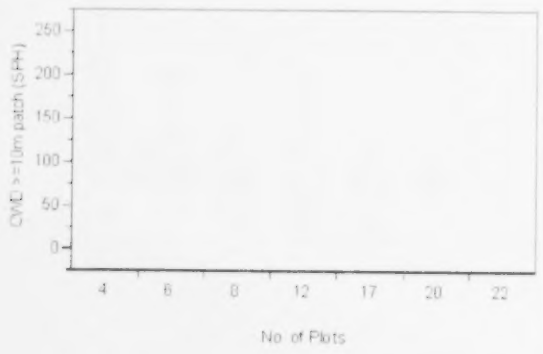

Figure 9. *Coarse woody debris ≥ 10 m patch (stems per hectare) by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

Precision for the two sampling designs with three patch plots (the 6- and 12-plot designs) is fairly low (about 57% of the estimate). Precision increases to 34% of the estimate for the 17-plot design, which has seven patch plots. The mean is consistent.

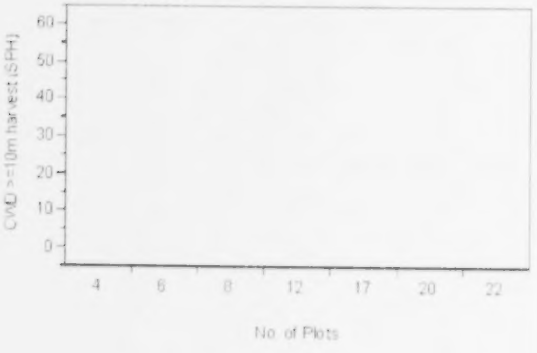

Figure 10. *Coarse woody debris ≥ 10 m harvest (stems per hectare) by number of plots for the 100 Mile House Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

A precision around the mean of 34% is not obtained until the 12-plot sampling design (nine harvest plots). The mean is consistent.

4.0 Summary and Recommendations for 100 Mile House Forest District Cutblock

- Modelling of the estimated number of tree species is necessary to counteract potential bias due to the different sampling intensity for the baseline and RSM datasets.
- With the high amount of dispersed retention in this block (about 20% retention from dispersed trees), an increased number of harvest area plots is necessary to increase precision for the following indicators: functional snags, large trees, CWD volume in harvested strata, and long pieces of CWD in harvested strata.
- Precision around CWD volume in the patch strata is good with one plot per hectare.
- The precision of CWD long pieces in the patch strata only gets to 34% with seven patch plots (two per hectare of patch retention). This sampling intensity is likely not operationally obtainable.
- **Recommendation for the 100 Mile House Forest District cutblock (ID 2964): six dispersed retention plots and three patch plots.**

5.0 KALUM FOREST DISTRICT CUTBLOCK

The sampling designs and results for the Kalum Forest District cutblock (Opening ID 96275) are summarized in Tables 5 and 6, respectively.

Table 5. *Sampling designs for dispersed (D) and patch (P) strata (NAR and wildlife tree patches [WTP]) in the Kalum Forest District cutblock (Opening ID 96275)*

	NAR	WTP1	WPT2	WTP3	WTP4	WTP5		
	DO[b]	PR	PW	PW	PW	PW		
Design	28 ha	3.68 ha	3.44 ha	1 ha	1.5 ha	1.5 ha	Total no. plots	No. replicates
D = 1; P = 1/3 ha	1	1	1	1	1	0	5	50
D = 2; P = 1/2 ha	2	2	2	1	1	0	8	50
D = 1; P = 1/ha	1	4	3	1	1	0	10	50
D = 3; P = 1/ha[a]	3	4	3	1	1	0	12	50
D = 6; P = 2/ha	6	8	6	2	1	0	23	50
D = all; P = 3/ha	8	12	9	3	1	0	33	50
D = all; P = all	8	13	10	4	1	0	36	1

a Currently recommended sampling intensity.

b Stratum types used: dispersed other (DO) - stratum containing dispersed trees left outside of a riparian management area for purposes other than riparian or wildlife tree retention and anticipated to remain for the full rotation, patch riparian (PR) treed patch left within a riparian management area. and, patch wildlife (PW) – treed patch left outside of RMA and designated as a wildlife tree patch.

Table 6. *Summary statistics for five sampling designs plus all plots in the Kalum Forest District cutblock (Opening ID 96275)*

Indicator	Statistic	D = 1 P = 1/3 ha (5 plots)	D = 2 P = 1/2 ha (8 plots)	D = 1 P = 1/ha (10 plots)[a]	D = 3 P = 1/ha (12 plots)[a]	D = 6 P = 2/ha (23 plots)	D = all P = 3/ha (33 plots)	D = all P = all (36 plots)
Class 3+ wildlife tree with height ≥ 10 m and dbh ≥ 30 cm (no. per hectare)	Mean	17.6	19.3	19.8	20.7	21.2	20.8	20.6
	S.D.	16.9	13.8	9.2	9.1	5.6	1.9	
	Min.	0.0	0.0	2.5	2.3	8.7	16.3	
	Max.	57.0	57.7	41.4	45.7	30.6	23.5	
Trees with dbh ≥ 70 cm (no. per hectare)	Mean	15.0	13.9	14.3	14.5	14.4	14.5	14.5
	S.D.	5.1	3.2	2.4	2.4	1.1	0.4	
	Min.	8.6	8.8	10.0	9.6	12.5	13.1	
	Max.	30.1	22.2	19.4	20.0	16.6	15.3	
Number of tree species	Mean	3.3	3.5	3.6	3.4	4.4	4.6	5.0
	S.D.	0.5	0.6	0.6	0.5	0.7	0.5	
	Min.	3.0	3.0	3.0	3.0	3.0	4.0	
	Max.	5.0	5.0	5.0	5.0	5.0	5.0	
Estimated number of tree species	Mean	3.4	3.5	3.6	3.4	4.9	5.2	6.0
	S.D.	0.7	0.7	0.8	0.6	1.1	1.0	
	Min.	3.0	3.0	3.0	3.0	3.0	4.0	
	Max.	6.0	6.0	6.0	6.0	6.0	6.0	

Indicator	Statistic	D = 1 P = 1/3 ha (5 plots)	D = 2 P = 1/2 ha (8 plots)	D = 1 P = 1/ha (10 plots)[a]	D = 3 P = 1/ha (12 plots)[a]	D = 6 P = 2/ha (23 plots)	D = all P = 3/ha (33 plots)	D = all P = all (36 plots)
CWD volume (m^3/ha) – patch	Mean	209.5	211.0	226.6	219.6	223.4	222.0	221.7
	S.D.	56.1	40.5	22.7	24.5	18.5	7.5	
	Min.	117.0	139.1	166.6	151.7	188.3	207.0	
	Max.	320.7	299.2	270.4	262.6	256.1	238.5	
CWD volume (m^3/ha) – harvest	Mean	355.3	353.7	317.9	353.9	364.5	361.9	361.9
	S.D.	193.8	139.7	196.8	109.1	48.4	0.0	
	Min.	100.4	109.3	100.4	161.9	265.7	361.9	
	Max.	673.3	650.5	673.3	589.0	421.3	361.9	
CWD with length ≥ 10 m (no. per hectare) – patch	Mean	69.9	71.9	72.6	70.4	70.3	69.5	69.8
	S.D.	27.2	17.0	11.6	11.8	6.0	2.8	
	Min.	33.3	33.3	50.0	46.9	54.1	62.3	
	Max.	141.3	106.6	98.5	97.6	84.3	73.9	
CWD with length ≥ 10 m (no. per hectare) – harvest	Mean	26.5	22.8	20.9	22.6	24.3	23.4	23.4
	S.D.	23.6	16.7	24.3	13.4	5.4	0.0	
	Min.	0.0	0.0	0.0	0.0	14.5	23.4	
	Max.	52.4	52.4	52.4	50.8	31.2	23.4	

a Currently recommended sampling intensity.

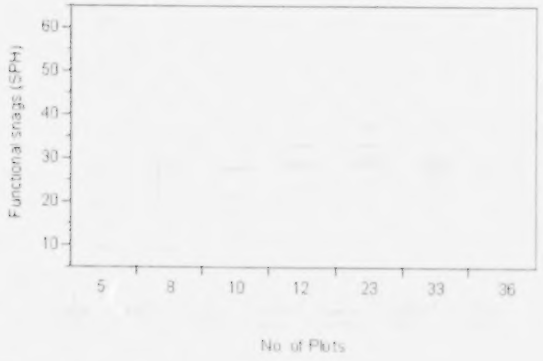

Figure 11. *Functional snags (stems per hectare) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

Since the harvest area contained no dispersed retention, the data on functional snags for this cutblock comes only from the patch plots. The respective number of patch plots for the sampling designs are: 5-plot (four patch plots), 8-plot (six patch plots), 10- and 12-plot (nine patch plots), 23-plot (17 patch plots), 33-plot (25 patch plots), and 36-plot (28 patch plots). The current recommended number of plots for this Kalum Forest District cutblock is 12 (three plots in harvest area and nine plots in the retention patches). With the recommended number of plots, the sampling precision is somewhat low at 44%. The mean remains fairly consistent among the sampling designs.

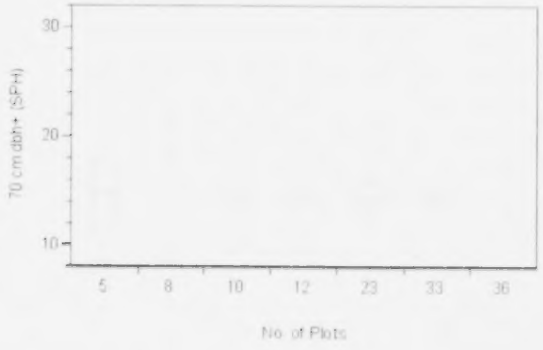

Figure 12. *Large trees 70 cm dbh+ (stems per hectare) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The 10- and 12-plot designs both have nine patch plots, the recommended number for this block (total of 11 ha of patch retention). The mean from the 50 replicates (green line) remains fairly stable in all the sampling designs. All sample designs produced adequate precision (less than 35%) for sampling the density of large trees. The mean was fairly consistent among all sampling designs.

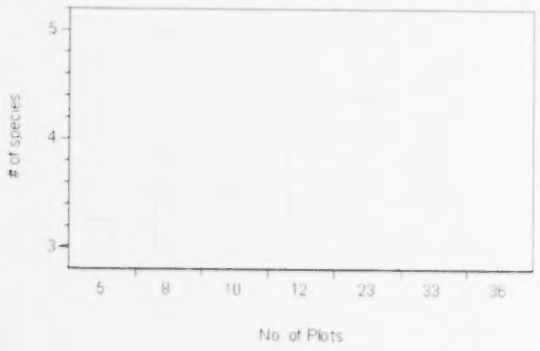

Figure 13. *Number of tree species by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The mean number of tree species found was higher with the three high-intensity sampling designs (23, 33, and 36 plots), compared to the lower-intensity sampling designs. The mean is highly variable.

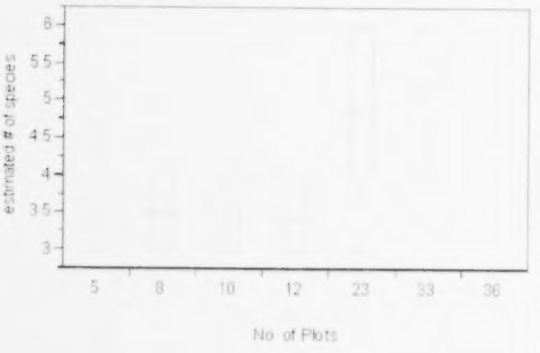

Figure 14. *Estimated number of tree species by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The estimated total number of species is less variable than the number of species sampled, but still shows some bias for small samples (which is to be expected). The Chao estimate is actually a lower limit for the total number of species. The stratified sampling design complicates estimation of the total number of species, so the design was ignored. Instead, the same species were assumed to occur with equal frequency in all strata, which may not be a reasonable assumption. More research is needed to determine the best method for estimating the number of species.

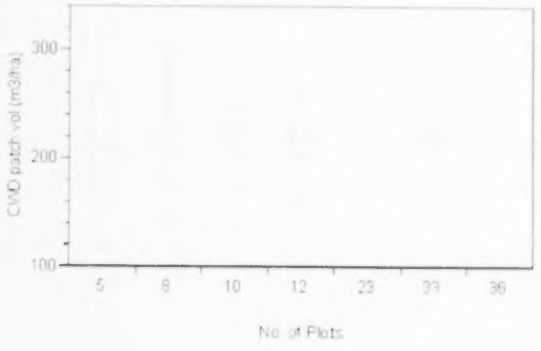

Figure 15. *Coarse woody debris patch volume (m^3/ha) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The CWD patch volume comes only from the retention patch plots. The 10- and 12-plot designs both contained nine patch plots and a precision of about 10–12% of the estimate, with no evidence of inconsistency. The mean is relatively stable for all sample designs, and precision was acceptable (> 35%) for all sampling intensities.

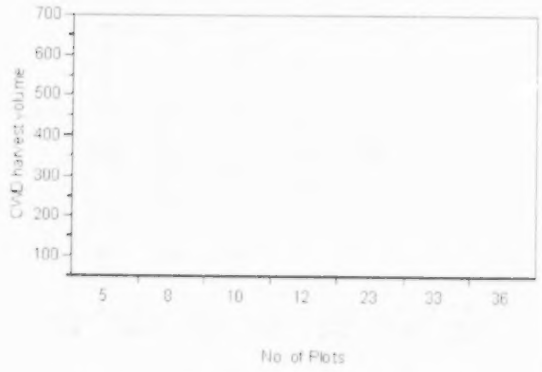

Figure 16. *Coarse woody debris harvest volume (m^3/ha) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

The CWD harvest volume comes only from the harvest or dispersed plots. The sampling designs had the following number of harvest plots: 5-plot (one harvest plot), 8-plot (two harvest plots), 10-plot (one harvest plot), 12-plot (three harvest plots), 23-plot (six harvest plots), 33-plot (eight harvest plots), and 36-plot (eight harvest plots). All designs appear consistent with respect to the mean. Two harvest plots gave insufficient precision at about 39% of the estimate. Three harvest plots (12-plot design) gave an acceptable degree of precision of about 31%.

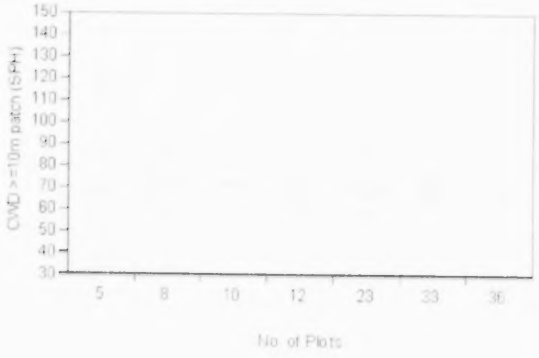

Figure 17. *Coarse woody debris ≥ 10 m patch (stems per hectare) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

All designs appeared consistent in the mean. Sufficient precision (24%) was found with six patch plots, or about one plot per 2 ha of patch retention.

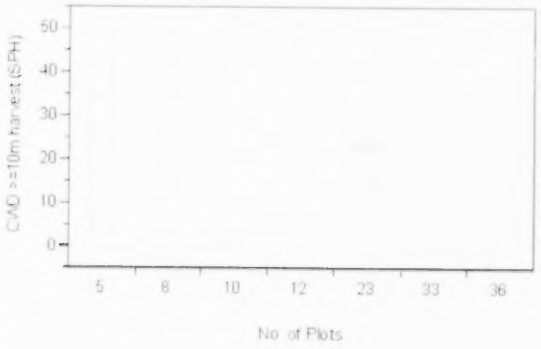

Figure 18. *Coarse woody debris ≥ 10 m harvest (stems per hectare) by number of plots for the Kalum Forest District cutblock. The red box represents the half of the values that lie between the 25th and 75th quartiles; the whiskers extend to the outermost values; the red line across the middle of the box is the median and the green line is the mean.*

All designs appeared consistent in the mean density of long pieces of CWD. Acceptable precision (22% of the estimate) was obtained with six harvest area plots (23-plot design). The 3-plot design (12 total plots) had a higher variability (59% of the estimate).

6.0 SUMMARY AND RECOMMENDATIONS FOR KALUM FOREST DISTRICT CUTBLOCK

- Modelling of estimated tree species for the RSM sampling and the baseline is necessary to ensure that they are comparable.
- Considering operational realities, the variability in density of functional snags is too high to achieve 35% sampling precision with a reasonable number of plots.
- Large tree sampling at recommended plot densities gives good precision. Adequate precision was obtained at lower plot densities.
- Sampling for CWD volume in retention patches gave good precision at recommended patch sampling intensities, and adequate precision at lower plot densities.
- Sampling for CWD volume in the harvested strata gave adequate precision at the recommended plot densities.
- Sampling for CWD density of long pieces in patch retention gave good precision (17%) at recommended plot densities and adequate precision at lower plot densities.
- Variability of CWD density of long pieces in harvest areas was high; a 35% sampling precision would probably occur with about five harvest area plots. If assessment is necessary for the CWD piece length on a single block, then the sampling intensity should be increased. If looking at CWD piece length on many blocks is sufficient, and, considering that CWD volume precision is adequate and there are no dispersed standing trees, then the recommendation of three harvest area plots is adequate.
- **Recommendation for the Kalum House Forest District cutblock (ID 96275): nine patch plots and three harvest area plots.**

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7.0 CONCLUSIONS

The number of tree species found is highly dependent on sampling intensity; therefore, care must be taken to ensure that comparisons with baseline indicators are limited to datasets that represent similar sampling intensity or are based on suitable estimates of the total number of species (i.e., found plus missed).

Variability of functional snag density was high for both the 100 Mile House and Kalum Forest District cutblocks. This means that, operationally, we may not be able to install enough plots to achieve good precision. Any assessment of a single cutblock for this indicator should be done cautiously.

The precision surrounding the large tree density and the CWD indicator are likely sufficient for the recommended plot density with low levels of dispersed retention. In areas with high levels of dispersed retention, more than three harvest area plots should be established.

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Sampling Intensity for
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Report No.15
April 2008

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